



# DESIGN AND BUILD OF AN AUTOMATED ANIMAL FEED DISPENSER

by

Soroush Sedigh

BioResource and Agricultural Engineering  
BioResource and Agricultural Engineering Department  
California Polytechnic State University  
San Luis Obispo  
2016

TITLE: DESIGN AND BUILD OF AN AUTOMATED ANIMAL FEED DISPENSER

AUTHOR: SOROUGH SEDIGH

DATE SUBMITTED:

DR. BO LIU

---

Senior Project Advisor

---

Signature

---

Date

Dr. Charles Crabb

---

Department Head

---

Signature

---

Date

## **ACKNOWLEDGEMENTS**

Firstly, I would like to thank my parents, for their unwavering support during my college career, the entire BRAE department faculty and staff for providing an indispensable education, and lastly my senior project advisor, Dr. Bo Liu, for all his support and help throughout this project.

## **ABSTRACT**

This senior project discusses the design, construction, and evaluation of automated animal feed dispenser on a small-scale level. The system consists of three main components with various sub-components. Those three components are the outer-casing, the hardware and circuitry, and lastly the code to make sure the hardware operates properly.

System tests have indicated that the feed dispenser is able to provide one week's worth of feed to the end user with no human interference.

## **DISCLAIMER STATEMENT**

The university makes it clear that the information forwarded herewith is a project resulting from a class assignment and has been graded and accepted only as a fulfillment of a course requirement. Acceptance by the university does not imply technical accuracy or reliability. Any use of the information in this report is made by the user(s) at his/her own risk, which may include catastrophic failure of a device or infringement of patent or copyright laws.

Therefore, the recipient and/or user of the information contained in this report agrees to indemnify, defend and save harmless the State its' officers, agents and employees from any and all claims and losses accruing or resulting to any person, firm, or corporation who may be injured or damaged as a result of the use of this report.

## TABLE OF CONTENTS

	<u>Page</u>
SIGNATURE PAGE.....	ii
ACKNOWLEDGEMENTS.....	iii
ABSTRACT.....	iv
DISCLAIMER STATEMENT.....	v
LIST OF FIGURES.....	vii
LIST OF TABLES.....	viii
INTRODUCTION.....	1
LITERATURE REVIEW.....	3
PROCEDURES AND METHODS.....	7
Overview.....	7
Materials Procurement.....	7
Electronic Configuration.....	8
Construction of Storage and Casing.....	16
Testing.....	18
RESULTS.....	19
DISCUSSION.....	20
RECOMMENDATIONS.....	22
REFERENCES.....	23
APPENDIX A.....	24
APPENDIX B.....	26
APPENDIX C.....	29

## LIST OF FIGURES

1. Figure 1: Methodology for a remote controlled fish pellet dispenser.....	3
2. Figure 2: System Interface Conditions.....	4
3. Figure 3: A rat utilizing the automatic feed dispenser system.....	5
4. Figure 4: Wiring Schematic of System.....	9
5. Figure 5. Circuit Diagram for System.....	9
6. Figure 6: Load Cell Specifications.....	10
7. Figure 7: HX711 Operating Specifications.....	11
8. Figure 8: Z Plate Configuration of Load Cell.....	11
9. Figure 9: Esumic LCD Pin Description.....	13
10. Figure 10: Acrylic Disc and Separator .....	14
11. Figure 11: Flow of Feed from Storage to Distribution Device to Dish.....	14
12. Figure 12: Design of System.....	15
13. Figure 13: Construction of Casing.....	16
14. Figure 14: Addition of Guiding Panels.....	17
15. Figure 15: Completed Product.....	18



## LIST OF TABLES

1. Table 1: Arduino Duemilalove Specs.....	6
2. Table 2: Esumic LCD Pin Descriptions.....	13
3. Table 3: Results of Testing.....	19
4. Table 4: Cost Breakdown of Materials List.....	21

## INTRODUCTION

### **Background**

Animal feed distribution systems are a very common item and are used greatly both on a domestic scale as well as on a larger scale in commercial applications. Animal feed distribution systems come in many different forms with different ways to control how the feed actually gets distributed. Whether it is a manual system, an automatic system on a timer, or a sensor based system; there are many different ways to accomplish the same end outcome, with some of the routes being more efficient than others. The use of sensors is a huge added benefit when it comes to feed systems because it automates the process completely, allowing for minimal human interference. Many users are looking for a system that is not only capable of running on its own, but also one that is visually appealing. In today's college culture, many young adults are looking for a new experience, and one of these experiences is bringing a pet of some sort home. Whether it be a dog, cat, hamster, or any other sort of pet, these animals need to be properly cared for and nourished. Often times, a source of stress for these animals can be not getting fed the proper amounts of feed or not getting fed on time. This is a sad reality that leads to malnourishment and eventually abandonment of these animals. In addition, many times feed will come in an airtight bag that pet owners can forget to close up completely after feeding pets. This leads to things like growing mold spores and bacteria cultures in the feed itself. All these reasons come together to pose the question of: "Is there a better way to do this?", and the answer is yes.

### **Justification**

Many animal feed systems can be designed to function as an automatic device, that allow the user to predetermine when the feed is distributed from a pre-set list of parameters that may include a per time basis, a per weight basis, or even on a proximity basis that depends on the position of the animal in relation to the feed distribution system. The purpose of having sensors in a system like this is to automate the feed process completely. In addition to having a single sensor in a system like this, it is possible to incorporate other aspects to the system, to make it more efficient and user friendly. The use of things like LCD displays, weight sensors, and servo-motors all the individual components of the system to work together in order to provide an efficient and easy way to control and monitor the feed levels in a system like this. Though systems like this exist in the real world, they are often complicated, provide many unnecessary services, and can be very pricy to someone who is on a college budget. These factors often lead to students throwing out the idea of an automated feeder, an instead leads to them settling for manual feeding, which can often be late, inconsistent, and in some cases, unsanitary. These are all factors that need to be considered when caring for the life of another being, and should be considered in the construction of this project.

**Objective**

The objective function of this project is to design and build the hardware for a dog feed distribution system that would operate on a sensor basis through the use of a load cell, an LCD display, and a servo motor. It will provide schematics to be used for the wiring of the system, images and procedures for the construction of an aesthetically pleasing and useful outer-casing, as well as the code developed that is necessary to ensure every component does its job. Constraints of the system would be that the actual hardware would need to be able to be confined to the end user's available area of use. Although this is different for everyone, for this specific project, the system will be held in a 2 ft x 2 ft x 1 ft environment.

## LITERATURE REVIEW

The purpose of this literature review is to provide insight on existing knowledge in the field of sensors, remote sensing and control, and automatic feed dispensers for animals. Through extensive research, a number of scholarly articles and conference proceedings were read and analyzed for any pertinent information on the topic at hand. In today's society, the use of technology to remotely control a series of processes is becoming more and more prominent. Through the use of MCU's and a well built and designed feed distribution system, it is possible to completely automate and separate the feeding process from any personal physical requirement and greatly reduce labor costs on a larger scale level.

### Automatic Feed Dispensers:

A very efficient way to design one of these feed dispensers is through the use of a PIC microcontroller. The simple elements of a design utilizing a microcontroller or MCU would be with a storage compartment, some sort of stand, and a direct current motor (DC motor). To control when the pellets would be dispensed, the system would utilize a control system, whose parameters can be defined by the user beforehand (Noor and Hussain, 2012). In addition to predefined conditions to which the system would dispense feed, another way to control this function would be through the use of a timer, which would engage the motor at the given time and allow it to dispense the feed. How much feed would be controlled by how quick the motor spins, with a larger gap time allowing more feed to be dispensed (Noor and Hussain, 2012). One of the perks of having a system that runs like this is that the risk of overfeeding is also greatly reduced. In addition to that, the required maintenance of this system is much less than a traditional system. The major methodology used in an automatic fish pellet dispenser, can be seen below in figure 1.

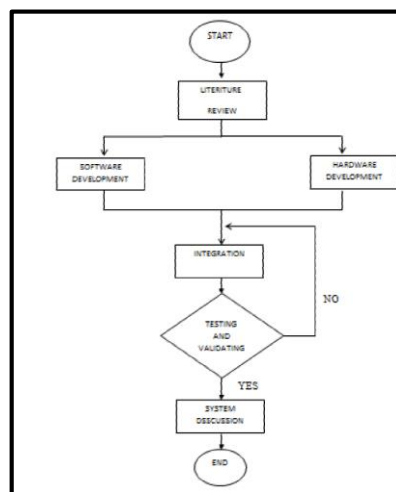


Figure 1. Methodology for a remote controlled fish pellet dispenser (Noor and Hussain, 2012).

The literature review was used to analyze prior research and see what the shortcomings in similar projects were. Once these shortcomings were identified, it would then be possible to address these issues in the hardware and software development stage, which would then be used in the integration step to get the system up and running. When the system is running, it is then important to do tests on it in order to ensure that it operated under the desired conditions. The results of the testing and validation is then discussed and improvements to the system are made (Noor and Hussain, 2012). In terms of controlling the motor, the automatic fish feeder system utilized a L293D motor driver, which has a drive current ranging up to 600mA and a voltage varying from 4.5-36V. In this application, the motor driver was used to control the rotational motor speed, therefor controlling how much feed was actually dispensed (Noor and Hussain, 2012). The logic and parameters used for this function can be seen in figure 2 below.

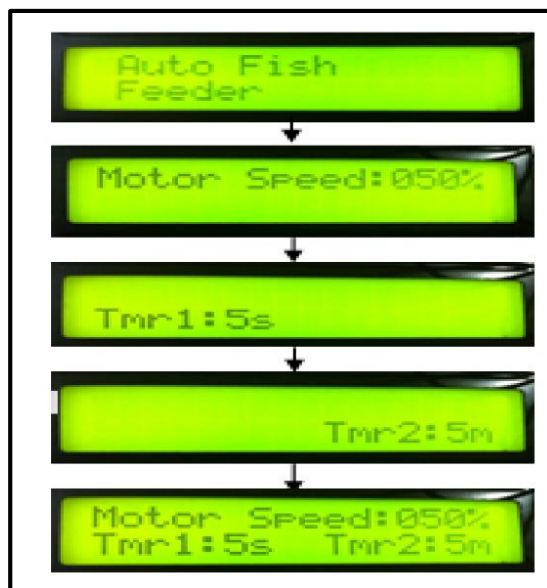


Figure 2. System Interface Conditions (Noor and Hussain, 2012).

In addition to the use of a timer, these feeding systems are often weigh feeders because the rate of distribution can be controlled using PI control. The basic methodology for a PI control is governed by the following set of laws:

$$\Delta u(k) = C(z^{-1})r(k) - C(z^{-1})y\Delta(k) \quad \text{Eq. (1)}$$

$$C(z^{-1}) = k_p \left( \Delta + \frac{T_s}{T_i} \right) \quad \text{Eq. (2)}$$

$$e(k) = r(k) - y\Delta(k) \quad \text{Eq. (3)}$$

$$y\Delta(k) = (1 - z^{-1})y(k) \quad \text{Eq. (4)}$$

In equations 1-4 for governing PI control above, the variables can be defined as  $y(k)$  = flow rate,  $r(k)$  = reference input,  $T_s$ =sampling time,  $K_p$  = proportional gain, and  $T_i$ =integral time (Tajika and Sato, 2014).

In terms of materials for the storage and outer casing, there are a few requirements that must be met. One of these requirements involves making sure that the material selected for the drum coincides with the torque generated by the servo motor (Christ and Hoffman, 2012). In a study done in Biomed Tech Journal, a PVC storage container was used because it could adequately handle the torque from the servo motor. Another important consideration in the design of the system is to ensure that the dispenser has an adequate stop function so that the feed does not end up getting grinded by the servo plate. In order to make sure this does not happen, the correct slope for the dispensing of feed must be chosen so that it does not jam against the servo plate as it rotates (Christ and Hoffman, 2012). A design that utilizes these components can be seen below in figure 3.

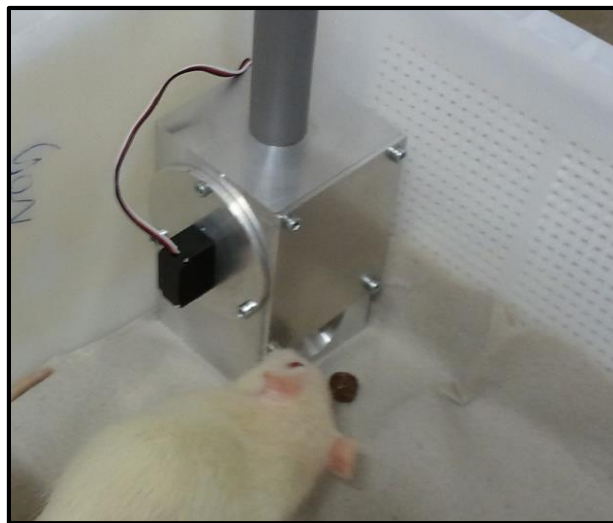


Figure 3. A rat utilizing the automatic feed dispenser system (Christ and Hoffman, 2012).

### **Data Acquisition system:**

Acquiring and sending data from a sensor to an Arduino and in turn to a wireless device requires some sort of wireless system such as Wi-Fi (Shajahan, 2014). It is essential that the MCU chosen has Ethernet or Wi-Fi capabilities to ensure that data can be transmitted to a remote mobile device for monitoring. In a system used to remotely monitor the energy consumption of a device, an Arduino was used where an Ethernet connection was used to send the data to an android platform (Shajahan, 2014). The MCU used was an Arduino Duemilanoove and is an open source microcontroller. The specifications of the MCU can be seen in figure 5 below.

Table 1. Arduino Duemilalove Specs (Shajahan, 2014).

Microcontroller	ATmega168/328
Operating Voltage	5V
InputVoltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	16 KB (ATmega168) or 32 KB (ATmega328) of which 2 KB used by bootloader
SRAM	1 KB (ATmega168) or 2 KB (ATmega328)
EEPROM	512 bytes (ATmega168) or 1 KB (ATmega328)
Clock Speed	16 MHz

In addition to the Arduino MCU, an Ethernet module was used to transmit the actual data to the android platform. The Ethernet module was an ENC28J60 and is a fully compatible Ethernet module that abides by IEEE code 802.3. It is able to operate at a supply voltage of 3.3V (Shajahan, 2014). In terms of software, all software development was done using Arduino IDE and Android SDK and eclipse for the mobile platform. The IDE communicates with the Arduino hardware and sends that signal to the platform using the Ethernet module (Shajahan, 2014).

## **PROCEDURES AND METHODS**

### **Overview**

The main purpose of this project was to introduce a product that didn't already exist in the market. After conducting market research, it was obvious that the current systems lacked in certain areas. For one, those that utilized any sort of display, were very expensive, making them a less attractive choice. The materials used to construct them were also a very cheap looking material that mimicked the appearance and feel of a two-liter soda bottle. On top of that, none of the existing systems were accessible on the inside, meaning that if any sort of hardware malfunction occurred, it would be very difficult to fix things. This project took into consideration all of these things, to help make a new system that had all of the desirable components just talked about.

The first step in the completion of this senior project was to define the necessary tasks that the feeder was to accomplish. By doing this, it would then be possible to organize a list of materials, as well as the most efficient way to go about design, construction, and testing of the apparatus.

The list of defined tasks for the feeder is as follows:

1. A system that is able to dispense feed automatically
2. The system will operate on a sensor basis, both time and weight
3. The system will have an LCD display that updates automatically, and displays the amount of feed left in the storage container.

As soon as the tasks were defined, it was then time to define the processes that the system would use to accomplish these tasks. Normal feeding habits for the end user in this case was twice a day, about 220 grams each time. Therefore, the basic methodology behind the process that was selected was that the weight sensor would take a reading every two hours for the feed storage container. From there, it would print the reading that it took, on the LCD display, visible for the user to see at all times. On the other hand, it was necessary for feed to be dispensed twice a day, once in the morning, and once at night. The servomotor would control this feature.

### **Materials Procurement**

Once the list of tasks had been defined, it was then possible to determine the materials needed to complete those tasks. In order to be able to carry out the defined functions automatically, a microcontroller would be needed so that the logic could be programmed into it. In order to be able to determine the fluctuating feed levels in the feed container, a load cell would need to be used, and because the feed would have to be automatically dispensed into the dish, a servomotor



would be needed to be able to operate the mechanism that allows feed to go from the storage compartment into the feed dish. Because it was important to be able to monitor the feed levels in the dish, an LCD display would be needed to be able to take the data that was read by the weight sensor and display it in a fashion in which the end user could easily be able to read a definitive amount of feed in the container. In the end, the microcontroller chosen would also need to be powered by something, and in this case the most practical way to do that was to use a battery.

In addition to the electronic portion of the system, there was also the casing, storage compartment, and feed dish portion of the system. It was determined that the outer casing would need to be constructed of something that was visually appealing, so a hardened plastic was chosen. The storage compartment would just be a section in the outer casing, separated by a panel from the electronic portion of the system. The feed dish would need to be machined to be able to fit within the restraints of the distribution system.

#### Electronic:

1. Arduino UNO R3 Board Module with DIP Atmega328P
2. Acrylic Transparent Arduino UNO R3 Base Plate & Terminal Optimizer Breadboard
3. 10kg 4-Wired Electronic Weighing Sensor
4. NEXT Keyes HX711 Load Cell Weighing Sensor AD Module for Arduino - Red ARD0536
5. RioRand® Spring SM-S4303R Large Continuous Rotation 360 Degree Plastic Servo for Robot(RR-BR301)
6. ESUMIC LCD Module for Arduino UNO R3 MEGA2560 16 X 2, 1602 White on Blue
7. 15Pcs 40 Pin 2.54 mm Single Row (L 11MM) Male Header for Arduino Prototype Shield DIY
8. MM Leads, FM Leads

#### Casing:

1. Feed Dish
2. Plexiglass for Casing and Storage
3. Steel for Z Plate Load Cell Configuration

### **Electronic Configurations**

In addition to fabrication of the storage and feed dish, one of the major components of this project was the electronic configuration and setup. This portion was split into a number of different section, as follows.

1. Configuration of Load Cell, Amplifier, Power, and Arduino.
2. Configuration of Servomotor, Power, and Arduino.
3. Configuration of LCD, potentiometer, Power, and Arduino.

Once the materials had been defined and ordered, it was then time to begin defining the script that would be used to carry out the necessary functions of the system. In order to do this, first the proper circuitry would have to be set up. The entire wiring schematic for the system can be seen in figure 4 below and following that the circuit diagram can be seen.

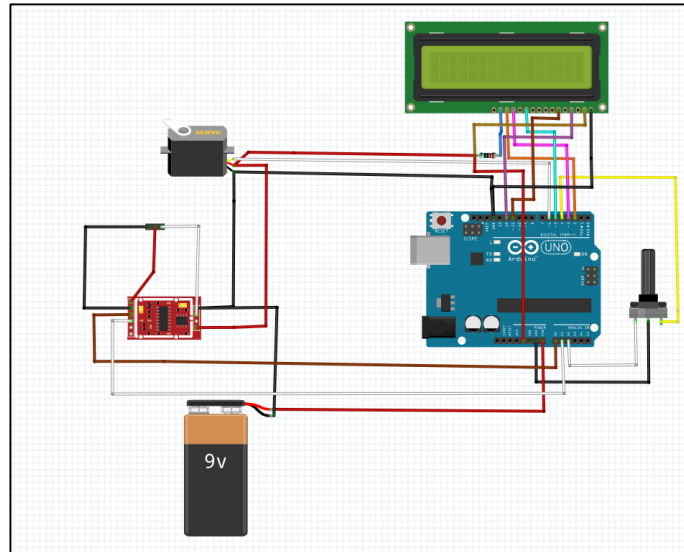


Figure 4. Wiring Schematic for the System

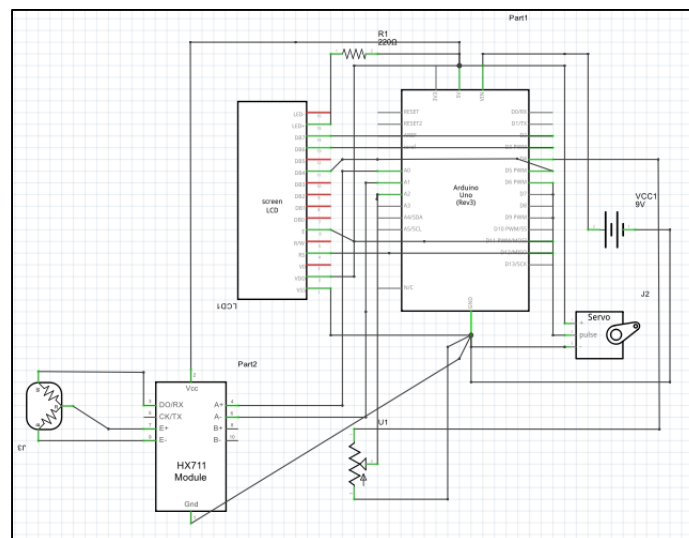


Figure 5. Circuit Diagram for System

The next step was to configure how the Arduino was going to interface with the load cell. A four-wire load cell was used along with a module that was necessary to amplify the signal received. The load cell itself was a simple parallel beam load cell made of aluminum with a cavity formed in the middle to allow it to be more susceptible to bending. The load cell contains four resistors, which form a Wheatstone bridge. When there is no stress on the beam, all four resistors are at rest and have a value of 350 ohms. When a load is applied to the beam, there is a change in resistance, which is then analyzed in a ratio to translate that into understandable data. This type of load cell can be found in kitchen appliances, electronic platforms, and other kinds of electronic weighing devices. The load cell dimensions can be seen below in figure 6. The load cell was selected upon the criteria that it had to be able to handle both the mass of the system as well as enough feed to last an entire week. Each feeding occurrence was designed to dispense one cup of feed, or 220 grams. That meant that to be able to contain a weeks' worth of feed, the load cell must have been able to handle 3,080 grams of feed, as well as the mass of the supporting structure. This took into account two feeding occurrences per day, for seven days. An analysis was done to determine the total weight of the system that would be supported by the load cell configuration, without any feed present in the system. That analysis can be seen in the casing section of the procedures. It was calculated that the total system, with a weeks' worth of feed, would weigh a little over nine kilograms. Because of this, a ten kg load cell was selected. There were also a number of considerations when it came to deciding on what kind of load cell to purchase. There were a number of options, such as miniature disc load cells, strain gauges, canister, and platform. While some of the options boasted capabilities such as water resistance, many of the extra functions were not necessary. In addition, because feed was going to be dispensed frequently, the most efficient way to measure differences in the mass of the system would be to use a load cell that measures displacement, in this case, a beam load cell. The other option for the function that needed to be accomplished here was a miniature disc cell, but the cost of those in comparison to the beam cell was much higher, due mainly to the fact that they are able to handle larger loads.

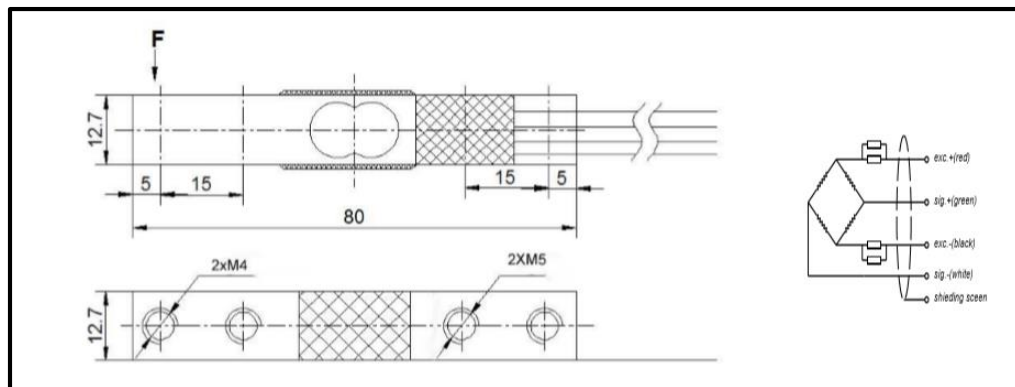


Figure 6. Load Cell Dimensions (Seidle, 2015)

Because the purpose of the load cell was to take readings on how much feed was remaining in the container, the system had to be calibrated to ignore the base weight of the container itself, and instead detect changes in the feed level. This was done in a series of steps that are as follows:

1. The four wire load cell was connected to an HX711 amplifier, which reads changes in resistance in the load cell. The specifications for it can be seen in figure 7 below.

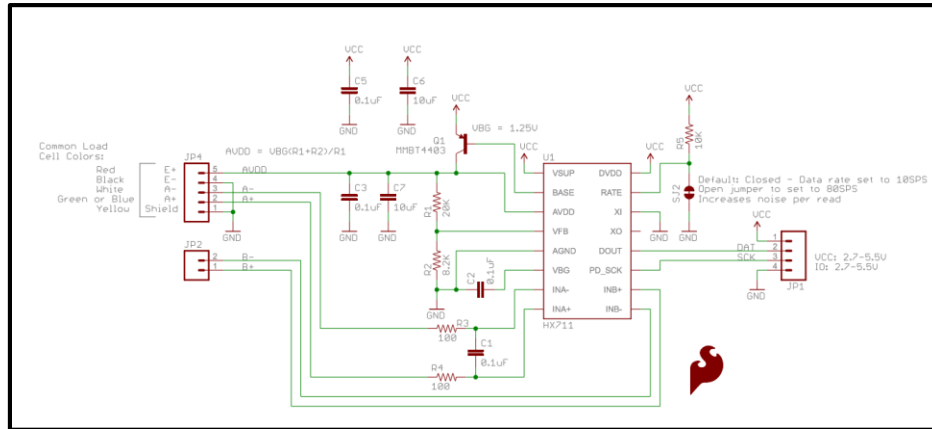


Figure 7. HX711 Operating Specifications (Seidle, 2015)

2. A z-plate configuration was used to orient the load cell. This was done through the use of 4 machine screws and 2 steel plates, that raised and lowered the plates a certain distance from the bar itself, to allow for more accurate data to be taken. This can be seen in figure 8 below.

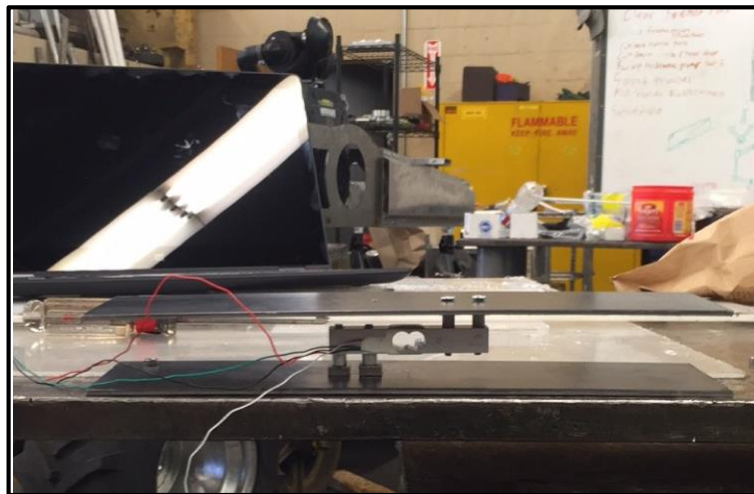


Figure 8. Z Plate Configuration of Load Cell

3. At this point, a calibration code from the manufacturer was uploaded to the Arduino, and once the script had been run, a series of values began to

show up in the serial monitor. These values would change once a certain amount of pressure was applied to the load cell.

4. The values in the serial monitor in step 3 were not that crucial, as what was important was how those numbers would change once a load was applied to bar. To do this, an average value was taken from the serial monitor, by adding a few lines to the calibration code. Once the code had been changed to take an average value, the number returned in the serial monitor was a lot more constant as time went on.
5. Next, the serial monitor was paused, and a value was chosen out of it. This value essentially represented what the load cell read when there was no load or pressure applied to it. That value was put back into the code itself, essentially zeroing the scale.
6. The next step was to apply a known weight to the load cell, so that a value could be obtained to see how far off the readings were from reality. The serial monitor was once again paused after about 10 seconds of taking readings, and the value was taken out and placed back in the line of code that calculated the weight reading. It was essentially the  $(\text{value read} - \text{the value from step 4}) / \text{value from step 6} \times \text{the known value of the calibration weight}$ . It should be noted that the value taken in this step was made a float value in order not to lose precision.
7. The average function was taken out so the load cell would be taking real time readings and displaying those, rather than a cumulative average over time.

The code that was used to calibrate the system utilizes the HX711 Arduino library. That and the general code used to send load cell readings to the Arduino can be found in appendix B.

The next step was to configure how the microcontroller was going to interface with the liquid crystal display, or LCD. The LCD chosen was an Esumic LCD Module that holds up to 32 characters over two separate lines of text. It operates at 5V DC and has white lettering on a blue backdrop for easy visibility. It is often used in copiers, fax machines, and industrial test equipment, making it a top choice for this application. The pin diagram for the LCD can be seen in the first figure below. The second figure is a description of the functions of those pins.

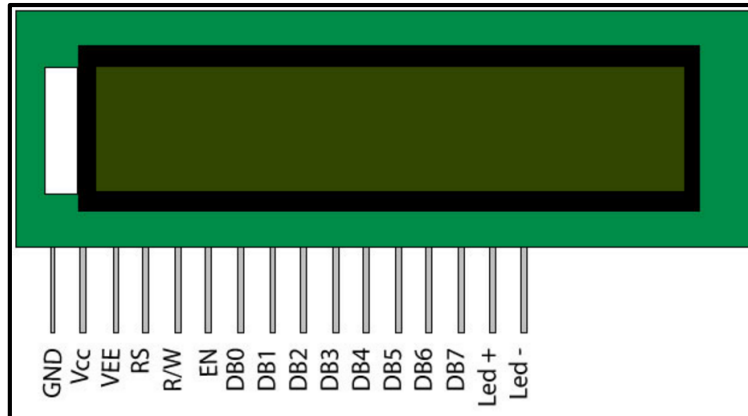


Figure 9. Esumic LCD Pin Diagram (Vishay, 2002)

Table 2. Esumic LCD Pin Descriptions (Vishay, 2002)

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; through a variable resistor	VEE
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bit data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V <sub>CC</sub> (5V)	Led+
16	Backlight Ground (0V)	Led-

In this system, a servomotor acted as an actuator. The basic design behind the actual feed mechanism utilized two rotating discs, two inches apart. They are separated into four quadrants by two intersecting pieces of acrylic that came together to form an X in the middle of the disc. The feed would be fed using the force of gravity, into the top quadrant. The Arduino would send a signal to the motor, which would then rotate 90 degrees clockwise. This created a force of momentum, which then emptied the feed into the dish. In order to prevent feed from filling into the incorrect quadrant, a two-inch-tall piece that was about 11.2" long was fitted around the other three quadrants. This ensured that when the servo rotated 90 degrees, no other feed was emptied into the other quadrants. The dimensions of the disc and cradle portion can be seen below in figure 10. The code for the distribution system is as follows:

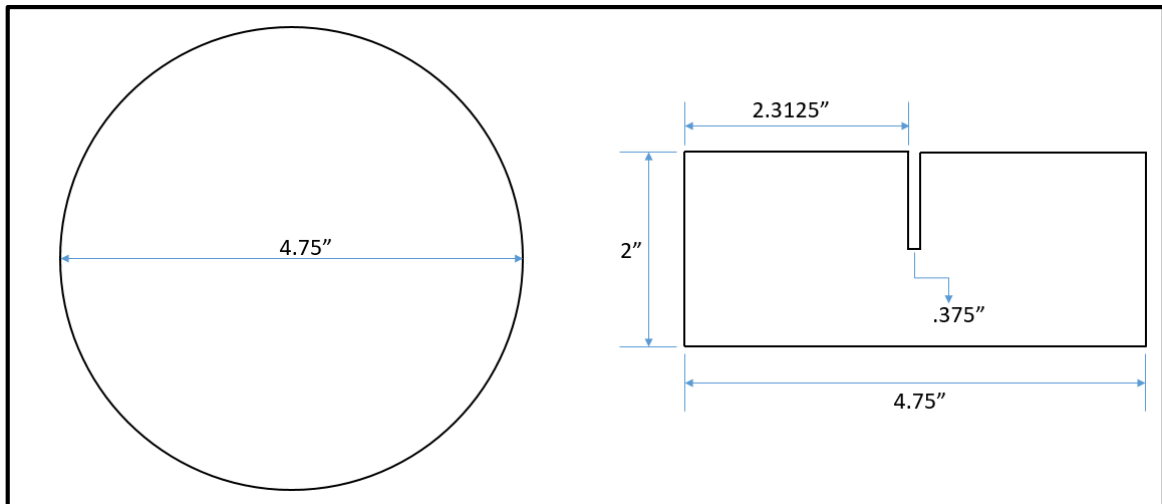


Figure 10. Acrylic Disc (2) and Separator (2)

The servomotor itself attaches to the center of one of the discs. There were a number of benefits to this design as opposed to others. The biggest was that this design ensured the same amount of feed was being emptied into the dish each time. In order to guide the feed from the storage portion into the dispensing mechanism, a set of ramps was cut out of Plexiglas, and attached to the side of the container and supported by two horizontal plates also cut out of Plexiglas, on their bottom sides. A diagram showing the flow of feed can be seen in the following figure.

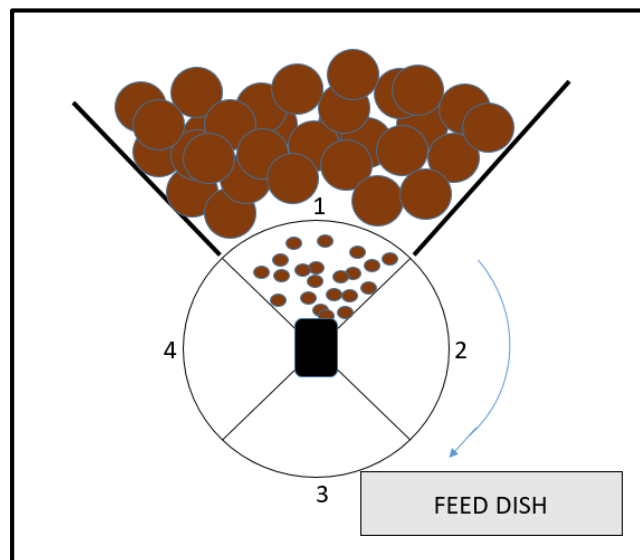


Figure 11. Flow of Feed from Storage to Distribution Device to Dish

The last step for the servomotor portion of the system was to develop the code. This was done using bits and pieces of other code found in the Arduino library. It can be found in appendix B. The entire design of the system, to be talked about in the following section, can be seen below in figure 12.

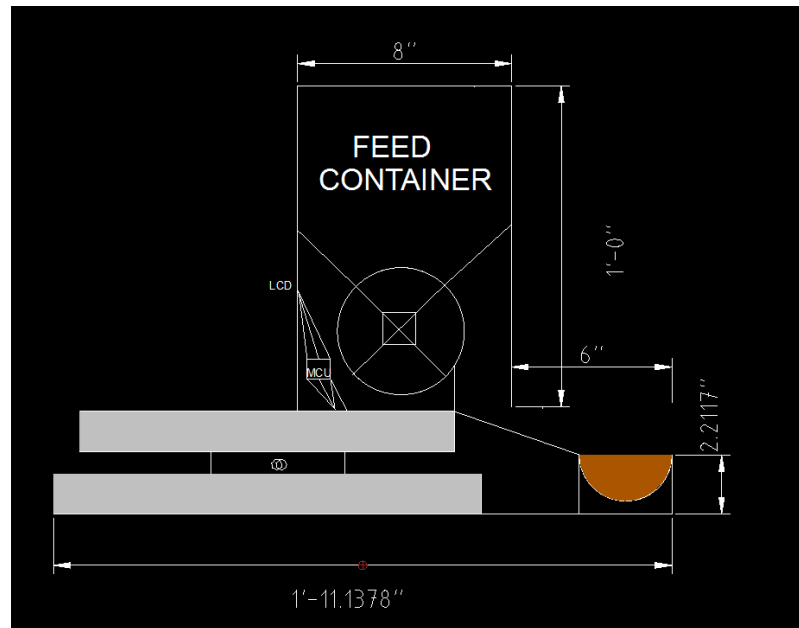


Figure 12. Design of System

### **Construction of Storage and Casing**

There were several considerations made prior to the construction of the both the outer casing of the system as well as the feed storage compartment. Firstly, the system had to abide by the system size requirements of 2' x 1' x 2'. Secondly, the storage compartment had to be a certain height to be able to account for the space needed by the feed dish as well as the fact that the feed needed to be able to be displaced into the bowl somehow.

The basic ideology behind the design incorporated several ideas in order to maximize efficiency as well as to ensure an aesthetically pleasing outcome. They are as follows:

- 1) Both the feed storage compartment as well as the circuitry box needed to be readily accessible.
- 2) The storage compartment needed to be designed to ensure that feed would readily be dispensed.
- 3) The aesthetic finish of the system needed to be pleasing to the eye.
- 4) It was necessary to design the system in a way to ensure that a LCD screen could be placed in a place that is easy to see and read.



- 5) The design on the system needed to account for the configuration and set up of the load cell.

The first step was to construct the plexiglass case that would encompass both the feed and the mechanical and electrical components of the system. The case was designed to be 14" tall and about 8" wide. First, the back and side panels were cut and fitted together using an epoxy adhesive. All pieces were cut on the vertical band saw. The next piece to be cut was the bottom panel. The piece was an 8" x 4" rectangle with a 2" piece taken out of the middle to allow for the feed to be dispensed out of. The figure below shows the back plate, side panels, and bottom piece put together. Full part drawings can also be seen in appendix c.

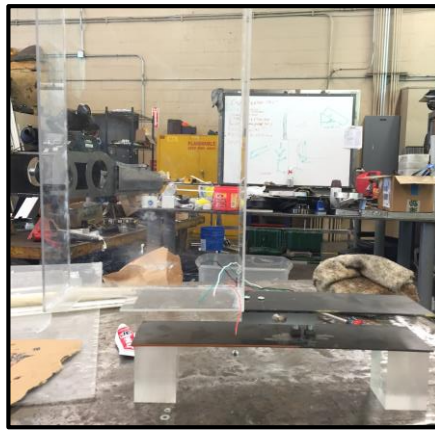


Figure 13. Construction of Casing

Next, the system that would dispense the feed was constructed. The servomotor was centered on the back plate, about two inches from the bottom, and was attached to the rotating discs by using the servo add on disc as well as an adhesive. Once the servo and wheel had been attached, a plate was added above the discs, similar to the bottom plate, to ensure that feed did not get into the electrical components of the system. It was also made of plexiglass, but this material was a  $\frac{1}{4}$ " thick, to be able to handle the load caused by the feed resting on it. Two diagonal panels were also added, to help guide the feed into the dispenser without allowing it to get caught in the corners of the casing. This can be seen in figure 14 below.

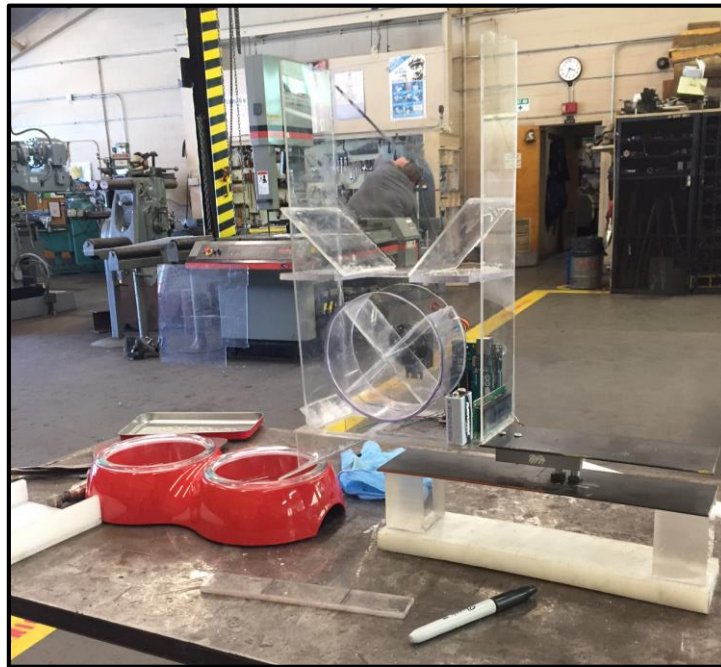


Figure 14. Addition of Guiding Panels

Once the interior portions of the system were constructed, it was time to construct the top piece as well as the front piece. A consideration that needed to be made here was that the electrical components of the system needed to be easily accessed, so any permanent type of bonding to the rest of the system was out of the question for the front plate. This left an option to use a lock and latch system, or some other type of adhesive. Because plexiglass can be easily cracked when drilling into, any sort of hinge was not a viable option, so it was decided that in order to have the front plate be completely removable, Velcro would be used to hold it in place while the dispenser was being used. As for the top piece, an HDPE plastic was used, and a lid was constructed by attaching 4 side panels to it, with a stainless steel handle on top to be easily applied and removed. The final product can be seen below in figure 15.

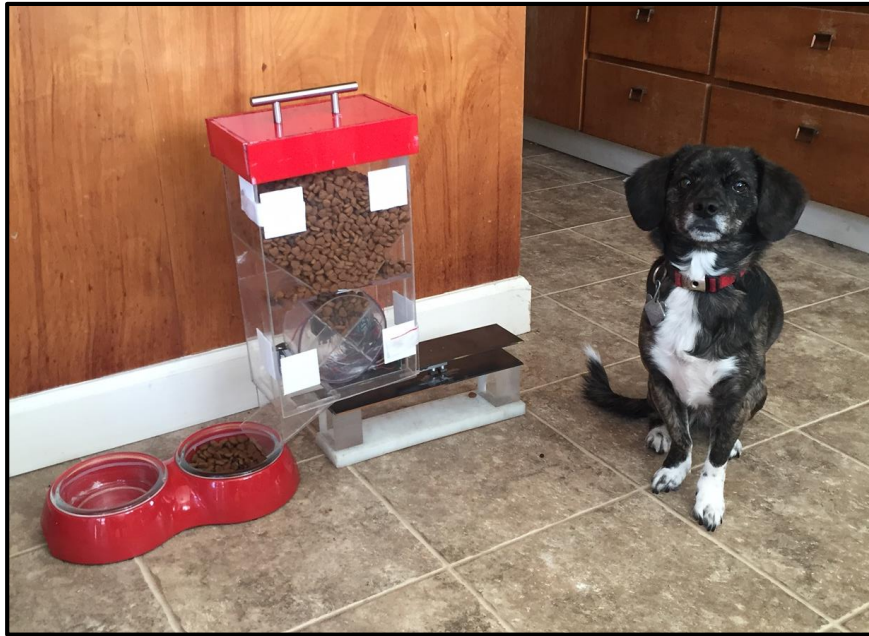


Figure 15. Completed Product

### **Testing**

When it came to testing the system, it was essential to not only ensure that the apparatus worked properly, but that it was consistent. To do this, a lists of test parameters were generated. Each of these parameters were assigned a point value of 1-point. There were a total of 10 parameters, and it was decided that the system would be tested a total of 10 times, for a possibility of 100 total points. A total score of 90 points or better, or an average of 90% on these tests would constitute a passing score. The parameters that were tested were split up into five different categories that can be seen below. Beneath each category a list of sub-categories can be found along with point values for each.

1. Dispenser Operates Correctly
  - a. The proper amount of feed is dispensed (1)
  - b. The feed is dispensed at the proper time interval (1)
  - c. The dispensing mechanism is structurally sound and does not flex or compromise its ability to function as a load is applied (1)
2. Support Structure for Casing
  - a. There is no structural flexing present on the outside panels as feed is refilled or dispensed (1)
  - b. The front panel of the system is easily removed to be able to access the electrical components, as well as the dispensing wheel for cleaning (1)

3. Load Cell
  - a. The load cell provides an accurate reading on remaining feed in the system. This was done by weighing the total amount first added to the system, and subtracting the feed that was dispensed after each feeding (1)
  - b. Structural design of the load cell is able to support the entire weight of the system while not being so rigid to the point where no resistance can be measured coming from the leads of the load cell (1)
4. LCD
  - a. The LCD displays the proper information (1)
5. Ease of Use
  - a. The end user (dog) feels comfortable approaching the system and is in no kind of danger from the apparatus (1)
  - b. The system is within the physical parameters of 2'x1'x2' that was set (1)

The results of these tests can be seen in the following "Results" portion of the report.

## RESULTS

In table 3 below, the final summary of the results of the testing procedure can be seen.

Table 3. Results of Testing

Category	Parameter	Point Value	Trial										Total By Parameter
			1	2	3	4	5	6	7	8	9	10	
Dispenser	Proper Amount	1	0	0	0	1	1	1	1	1	1	1	7
	Proper Time Interval	1	1	1	1	1	1	1	1	1	1	1	10
	Structural Integrity	1	0	0	0	1	1	1	1	1	1	1	7
Structural (Casing)	No Flexure on Panels	1	1	1	1	1	1	1	1	1	1	1	10
	Easily Accessible Front panel	1	1	1	1	1	1	1	1	1	1	1	10
Load Cell	Accurate Readings	1	1	1	1	1	1	1	1	1	1	1	10
	Structural Integrity	1	0	1	1	1	1	1	1	1	1	1	9
LCD	Displays Proper Information	1	1	1	1	1	1	1	1	1	1	1	10
Ease of Use	Safe and Easy to Use	1	0	0	0	1	1	1	1	1	1	1	7
	Obeys Physical Parameters	1	1	1	1	1	1	1	1	1	1	1	10
		<b>Final % by Trial #</b>	60%	70%	70%	100%	100%	100%	100%	100%	100%	100%	<b>90</b>
		<b>Final % Score of System</b>	<b>90%</b>										

The method used to determine whether or not the system was acceptable was a simple grading scale used in both educational and professional institutions. A 100-point scale was used, but rather than making the baseline for a passing score a 70, a 90-point value was used, to allow for some room for error in case portions of the system failed at any point during the testing procedure.

The system achieved an overall score of 90%, which was deemed acceptable because of the fact that a 100-point grading scale was used. The most problematic areas were the design of the dispenser, which allowed for bits of feed to flow down into the electrical components of the system. Because of this, the proper amount of feed was not dispensed the first few trials, but was remedied once the design was altered. In addition, the load cell was not adequately secured to the casing, causing a bit of instability. These factors led to an unsatisfactory score when it came to the ease of use category as well. However, once the design was altered and the casing was secured to the load cell, the issues were fixed.

## DISCUSSION

There were a number of issues that came up during the construction of this project. Often times, these issues needed to be dealt with as the project progressed. One of the biggest issues that was encountered, was that the use of plexiglass greatly inhibited methods that could be used to secure the system together. In this case, because the thickness of the material that was used was only 1/10" thick, the contact area between two plates was minimal, which resulted in larger set times, and a more careful approach to how pieces were clamped together. In addition, drilling into plexiglass often times leads to cracking, which not only looks aesthetically unpleasing, but also compromises the structural integrity of the system. Because of this, an epoxy was used, which led to some dripping. Although an acetone stripper was then used to thin the epoxy off, there was still some remaining resin, in the hard to reach areas of the system. Along those lines, because cracking the plexiglass was an issue, mounting both the MCU and the LCD became a bit of an issue. To remedy this, a plastic adhesive that was non-abrasive to the components of the MCU was used to attach it to the back panel, and the LCD was then wedged into the space between the MCU and the side panel, and was secured by adding a plastic spacer at the far end, that allowed for no lateral movement.

In terms of accuracy, the project is both accurate and precise in its methods. It accurately dispenses the proper amount of feed in a safe and repeatable way, while maintain a precise method that produces the same results every time. This statement is validated in the sense that the average value of dispensed feed was 218 grams. While the system was designed to dispense 220 grams, a difference of 2 grams accounts for less than one percent of the total value. This means that over a span of ten trials, the mean feed value was within one standard deviation. The project itself could be easily manufactured and repeated by an individual who has access to this report as well as an intermediate knowledge of how to work with the structural components of the system as well as a basic knowledge of Arduino functions and the components that can be used with it.

A cost analysis was done to evaluate whether or not it would be worth one's time and effort to construct a system such as this, or whether it would be more efficient to go with an existing system out there. The following table shows the cost breakdown for materials minus any costs associated with labor.

Table 4. Cost Breakdown of Materials List

Category	Item(s)	Description	# Units	\$/Unit	Total \$	Source
Scale	Load Cell	10 kg Straight Bar Load Cell	1	\$ 6.95	\$ 6.95	<a href="https://www.sparkfun.com">https://www.sparkfun.com</a>
	Z Plate	12" x 24" 16 gauge steel	1	\$ 18.25	\$ 18.25	<a href="http://www.homedepot.com">http://www.homedepot.com</a>
		M4 30mm Steel Panhead Screws	2	\$ 1.04	\$ 2.08	Ace Hardware
		M5 30mm Steel Panhead Screws	2	\$ 1.13	\$ 2.26	Ace Hardware
		M4 Steel Washers	2	\$ 0.65	\$ 1.30	Ace Hardware
		M5 Steel Washers	2	\$ 0.72	\$ 1.44	Ace Hardware
		1/4" x 1/2" Aluminum Spacers	4	\$ 1.10	\$ 4.40	Ace Hardware
	Amplifier	Load Cell Amplifier - HX711	1	\$ 9.95	\$ 9.95	<a href="https://www.sparkfun.com">https://www.sparkfun.com</a>
Dispenser	Outer Casing	30" x 60" x .100" Acrylic Sheet	1	\$ 38.99	\$ 38.99	<a href="http://www.acehardware.com">http://www.acehardware.com</a>
	Dispensing Wheel					
	Guides and Ramps					
	Motor	Radioshack Standard Servo	1	\$ 14.99	\$ 14.99	<a href="https://www.radioshack.com">https://www.radioshack.com</a>
Miscellaneous	Display	Esumic LCD Module for Arduino UNO R3	1	\$ 7.99	\$ 7.99	<a href="http://www.amazon.com">http://www.amazon.com</a>
	Microcontroller	Arduino Uno R3 Board	1	\$ 21.73	\$ 21.73	<a href="http://www.amazon.com">http://www.amazon.com</a>
	Male Pin Headers	15Pcs 40 Pin 2.54 mm Single Row Male Header	1	\$ 4.70	\$ 4.70	<a href="http://www.amazon.com">http://www.amazon.com</a>
	Cable	Male to Male, Female to Male	1	\$ 4.99	\$ 4.99	<a href="http://www.amazon.com">http://www.amazon.com</a>
	Power Cord	9V Battery Clip DC Adapter	1	\$ 5.99	\$ 5.99	<a href="https://www.amazon.com">https://www.amazon.com</a>
	Battery	Rayovac 9V Lithium Ion Battery	1	\$ 5.99	\$ 5.99	<a href="http://www.amazon.com">http://www.amazon.com</a>
				Total:	\$ 152.00	

With a total material cost of about \$150.00, it was a relatively low cost project that offers many perks and benefits in the long run. However, it is impossible to disregard the fact that in any normal situation, there would be a labor cost associated with a project like this. However, even before factoring labor costs, there are options out there in the market that are both more and less expensive versions of automated pet feeders. Whether one is looking for a gravity feeder with no moving components, or a more sophisticated system that operates on a schedule, there are a number of systems out there that would satisfy most needs. However, when labor costs get factored into this system, it becomes a little pricier. When factoring in labor costs, it is important to remember that in a manufacturing plant, labor costs would not be associated with design, but rather with the actual construction of the system. It is also important to remember that although this project took countless hours, for someone that has constructed many feed systems, the process would be less lengthy, so in this case, the cost of labor is a bit inflated. At about 50 hours of fabrication and 20 of software development, it is safe to say the project's physical preparation (without considering the time spent on the literature review or any other portion of the report or testing), took well more than what it would take in a manufacturing plant with access to production lines. Using the average college engineering grad's hourly pay rate of \$35.00/hr., the total cost of labor for this project is almost \$2500.00. This, however, is a number that should be considered with a grain of salt.

## RECOMMENDATIONS

There were a number of problematic areas when it came to the construction of the system. Because plexiglass was used to provide a more aesthetically pleasing finish, an epoxy had to be used to bind the casing together. This was due to the fact that plexiglass, if drilled into, has a tendency to crack, causing unwanted bumps in the material. The epoxy often dripped or ran down the side of the material, leaving a streak of resin behind. It is possible to remedy this however. The main time this was an issue, was when the pieces of material were not cut exactly straight or there were bumps on the material. This caused pieces to not come together properly, sometimes leaving gaps where they were joined. A way this could be remedied is through the use of laser etching. Because in this case, the material had been cut on a vertical band saw, and had to be hand fed into the blade, not every cut was perfect. The use of laser etching would help fix this problem, leading to less issues when it came to putting the pieces together.

Another recommendation would be on how to scale this project up for larger applications. The simple addition of a DC motor as well as a rotating agar would enable the user to pump out large quantities of feed in a short amount time, as well as provide more power for the user to handle larger pieces of feed.

A third recommendation would be the addition of a pressure pad directly in front of the feed dish. This would send a signal to the MCU once the animal was standing on the pad, to operate the servo and release feed. It essentially accomplishes the same end goal, but in this case it dispenses feed based on when the animal is hungry, rather than on a set feeding schedule.



## REFERENCES

1. Alfonso, J.P.V., P. Jhonatan, G.A.L. Felipe. 2014. Design of an automatic voice controlled system and remote control. Mechatronics Engineering Program, Department of Physics University of Caldas.
2. Aneiba, A., K. Hormos. 2014. A Model for Remote Controlled Mobile Robotic over Wi-Fi Network Using Arduino Technology. Faculty of Information Technology, Benghazi University-Libya.
3. Christ, O., U.G., Hoffman. 2012. A Remote Controlled Food Dispenser for Animal Research. Biomed Tech 2012; 57: 538-540.
4. Noor, M.Z.H, A. K. Hussian, M. F. Saaid, M. S. A. M. Ali, M. Zolkapli. 2012. The Design and Development Of Automatic Fish Feeder System Using PIC Microcontroller. 2012 IEEE Control and System Graduate Research Colloquium (ICSGRC 2012).
5. Seidle, N. 2015. HX711 Load Cell. HX711 Amplifier Hook Up Guide. Sparkfun Electronics. [https://cdn.sparkfun.com/datasheets/Sensors/ForceFlex/SparkFun\\_HX711\\_Load\\_Cell\\_v10.pdf](https://cdn.sparkfun.com/datasheets/Sensors/ForceFlex/SparkFun_HX711_Load_Cell_v10.pdf). March 28, 2016
6. Shajahan, A.H. 2014. Data acquisition and control using Arduino-Android Platform : Smart plug. Department of Electronics Engineering Madras Institute of Technology Campus, Anna University, Chennai.
7. Silva, J.F.M.C., D. Santos, V.C. Marques, K. Oliveira, T.O. Rodriguez, R.G.F. Texeira, J.W.M Menezes. 2012. A Study of Bluetooth Application for Remote Controlling of Mobile Embedded Systems. 2012 Brazilian Symposium on Computing System Engineering.
8. Tajika, H., T. Sato, Y. Ohnishi, T. Yamomoto, N. Araki, Y. Konishi. 2014. A Design Method of a Performance-adaptive Control System for a Weigh Feeder. Proceedings of the 2014 International Conference on Advanced Mechatronics Systems.
9. Vishay. 2002. 16x2 Character LCD. Vishay Datasheets. <http://www.engineersgarage.com/sites/default/files/LCD%2016x2.pdf>. March 28<sup>th</sup>, 2016

## **APPENDIX A: HOW PROJECT MEETS REQUIREMENTS FOR BRAE MAJOR**

### **Major Design Experience**

The BRAE senior project must incorporate a major design experience. Design is the process of devising a system, component, or process to meet specific needs. The design process typically includes fundamental elements as outlined below. This project addresses these issues as follows.

**Establishment of Objectives and Criteria.** Project objectives and criteria are established to meet the needs and expectations of all pet owners with a pet that is less than or equal to 30 pounds in weight. See *Design Parameters and Constraints* below for specific objectives and criteria for the project.

**Synthesis and Analysis.** The project incorporates process flow methodologies, control systems, and the consideration of new age technologies to simplify use for the end user.

**Construction, Testing and Evaluation.** The automated feed dispenser was constructed, tested, and evaluated for functionality.

**Incorporation of Applicable Engineering Standards.** The design and build of this project consisted of the basic engineering process for a design and build: Hypothesis, Planning, Design, Fabrication, Testing, Modifications.

### **Capstone Design Experience**

The BRAE senior project is an engineering design project based on the knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses). This project incorporates knowledge/skills from these key courses.

- BRAE 129 Lab Skills/Safety
- BRAE 133 Engineering Graphics
- BRAE 152 3-D Solids Modeling
- BRAE 216 Fundamentals of Electricity
- BRAE 328 Measurements/Comp Interfacing
- BRAE 433 Ag Structures Design
- EE 321/361 Electronics
- ENG 149 Technical Writing for Engineers

### **Design Parameters and Constraints**

This project addresses a number of the categories of the constraints listed below.

**Physical.** There is a 2' x 1' x 2' limitation on the design. This is to ensure that it does not take up too much room in the constrained area that is usually present where the feed dish of an animal is located.

**Economic.** Based on what is present in the current market, the total cost of the system was to be less than or equal to \$300.00. This was successfully met with a total cost of \$150.00.

**Environmental.** In order to be environmentally conscientious, the project was to be powered in a low power method that did not exceed 5kw-hr/month. This was met through the use of a 9V battery that power the entire system.

**Sustainability.** The system provides a sustainable method to automatically feed one's pet without any sort of emissions or by-products.

**Manufacturability.** The project was designed and built in a way so that anyone who reads the report, can duplicate the project. All code and wiring diagrams are recorded and available for re-use, as well as the construction portion of the outer-casing.

**Health and Safety.** All portions of the feed dispenser that come into contact with feed are made of materials that are safe for feed handling.

**Ethical.** There were no ethical considerations present during the design or build of this project.

**Social.** The purpose of this project was to improve the social process that is feeding one's pet. This was successful in the sense that the process is now much easier to carry out and maintain.

**Political.** There were no ethical considerations present during the design or build of this project.

**Aesthetic.** The overall appearance of the project had to be at a point in which one would want to have it in his/her home. This was achieved by using high grade plastic for the outer-casing.

**Other- Productivity.** The finished product was to be able to store at least a week's worth of feed to ensure that it would not have to be constantly refilled. This was met.

## APPENDIX B: PROGRAMMING

### Load Cell and Calibration:

//Property of Sparkfun Electronics

```

#ifndef HX711_h
#define HX711_h

#if ARDUINO >= 100
#include "Arduino.h"
#else
#include "WProgram.h"
#endif

class HX711
{
private:
    byte PD_SCK;    // Power Down and Serial Clock Input Pin
    byte DOUT;      // Serial Data Output Pin
    byte GAIN;      // amplification factor
    long OFFSET;    // used for tare weight
    float SCALE;    // used to return weight in grams, kg, ounces, whatever

public:
    // define clock and data pin, channel, and gain factor
    // channel selection is made by passing the appropriate gain: 128 or 64 for channel A, 32
    for channel B
        // gain: 128 or 64 for channel A; channel B works with 32 gain factor only
        HX711(byte dout, byte pd_sck, byte gain = 128);

    virtual ~HX711();

    // check if HX711 is ready
    // from the datasheet: When output data is not ready for retrieval, digital output pin DOUT
    is high. Serial clock
    // input PD_SCK should be low. When DOUT goes to low, it indicates data is ready for
    retrieval.
    bool is_ready();

    // set the gain factor; takes effect only after a call to read()
    // channel A can be set for a 128 or 64 gain; channel B has a fixed 32 gain
    // depending on the parameter, the channel is also set to either A or B
    void set_gain(byte gain = 128);

    // waits for the chip to be ready and returns a reading
    long read();

    // returns an average reading; times = how many times to read
    long read_average(byte times = 10);

    // returns (read_average() - OFFSET), that is the current value without the tare weight;
    times = how many readings to do
    double get_value(byte times = 1);

    // returns get_value() divided by SCALE, that is the raw value divided by a value obtained
    via calibration

```

```

        // times = how many readings to do
        float get_units(byte times = 1);

        // set the OFFSET value for tare weight; times = how many times to read the tare value
        void tare(byte times = 10);

        // set the SCALE value; this value is used to convert the raw data to "human readable"
        data (measure units)
        void set_scale(float scale = 1.f);

        // set OFFSET, the value that's subtracted from the actual reading (tare weight)
        void set_offset(long offset = 0);

        // puts the chip into power down mode
        void power_down();

        // wakes up the chip after power down mode
        void power_up();
};

#endif /* HX711_h */

```

### **General Code for LCD:**

//see [arduino.com](http://arduino.com) for more. Source code taken from manufacturer  
#include "HX711.h"

```

HX711 cell(3, 2);

#include <LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

int sensorValue = 0;
int sensorPin = A1;

void setup()
{
    Serial.begin(9600);
    Serial.println("Hello Mr. Sedigh");
    lcd.begin(16, 2);
}

void loop()
{
    lcd.begin(16, 2);
    lcd.setCursor(0,0);
    lcd.print("Weight measurement");
    sensorValue = analogRead(sensorPin);
    Serial.print(sensorValue);
    lcd.setCursor(0,1);
    lcd.print(sensorValue);
    delay(200);
}

```

**Servo:**

```

#define fill 20 //the position in degrees to fill the dispenser
#define empty 155 //the position in degrees to empty the dispenser
#define potPin A0 //this is the pin (analog) that middle lead of pot is connected to
#include <Servo.h> //

//variables
Servo mainServo; //declare the main servo
int trigger = 0; //this is used to switch between fill and empty
int potIn = 0; //this is the data read from pin A0 (the potPin)
int count = 1; //used as a time multiplier
void setup()
{
  //basic setup
  mainServo.attach(6); //tell arduino which pin the servo is on
  //set the pin modes
  pinMode(4, OUTPUT); //used to output 5V or High to the potentiometer
  pinMode(10, OUTPUT); //used for the led
  pinMode(11, OUTPUT); //used for the led

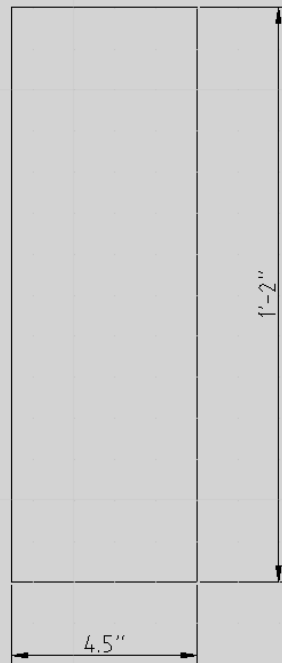
  digitalWrite(4, HIGH); //set pin 4 high
  digitalWrite(10, LOW); //set pin 10 low
}
void loop()
{

  potIn = analogRead(potPin); //read the position the potentiometer is at
  //if the trigger value is 0 fill the hopper
  if(!trigger)
  {
    mainServo.write(fill); //move servo to fill position
    //this is used to setup the delay
    //count = 171 //uncomment this to set the max delay to 3 hours
    //the delay below is calculated using potIn (which can be 0-1024) as delayinseconds ~= 0 - 64 seconds
    for(;count>=0;count--)
    {
      for(;potIn>0;potIn=potIn-20)
      {
        //this is to make the LED flash every 100+potIn milliseconds
        digitalWrite(11,HIGH); //set led to on
        delay(100+potIn);
        digitalWrite(11,LOW); //set led to off
        delay(100+potIn);
      }
    }
    count = 1;
    trigger = 1; //change trigger to 1 to setup empty
    digitalWrite(11,LOW); //set led off
  }
  else if(trigger)
  {
    mainServo.write(empty); //set the servo to empty position
    delay(1000); //delay while servo sets position
    trigger = 0; //change trigger to 0 to setup fill
  }
}

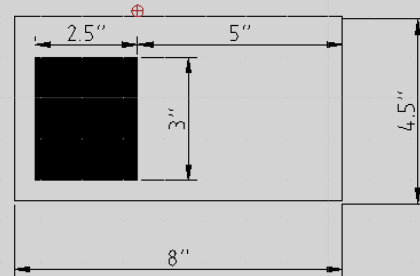
```

**APPENDIX C:  
PART DRAWINGS**

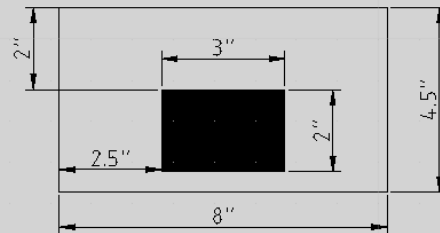
**Side Panels (2)**



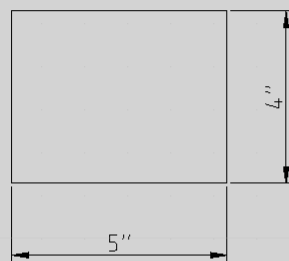
**Bottom Panel**



**Center Panel**



**Exit Ramp**



**Guiding Panels (2)**



**Exit Ramp Guides (2)**

